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Common ground in collaborative intelligence analysis: an empirical study

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This paper reports an empirical exploration of how different configurations of collaboration technology affect peoples' ability to construct and maintain common ground while conducting collaborative intelligence analysis work. Prior studies of collaboration technology have typically focused on simpler conversational tasks, or ones that involve physical manipulation, rather than the complex sensemaking and inference involved in intelligence work. The study explores the effects of video communication and shared visual workspace (SVW) on the negotiation of common ground by distributed teams collaborating in real time on intelligence analysis tasks. The experimental study uses a 2x2 factorial, between-subjects design involving two independent variables: presence or absence of Video and SVW. Two-member teams were randomly assigned to one of the four experimental media conditions and worked to complete several intelligence analysis tasks involving multiple, complex intelligence artefacts. Teams with access to the shared visual workspace could view their teammates' eWhiteboards. Our results demonstrate a significant effect for the shared visual workspace: the effort of conversational grounding is reduced in the cases where SVW is available. However, there were no main effects for video and no interaction between the two variables. Also, we found that the "conversational grounding effort" required tended to decrease over the course of the task.

Shared Visual Workspace, Video, Collaborative Intelligence Analysis, Sensemaking, Common Ground, Grounding, Conversational Grounding Effort.

1. INTRODUCTION

A range of sophisticated skills, expertise and methodologies beyond the ones a single analyst working alone can provide, is needed to collaboratively acquire, develop, integrate, process and accurately analyse a wide-range of terrorism-related evidence from mixed sources, in order to combat or prevent terrorism. Further, for counter-terrorism initiatives to yield more dividends, the antiquated and dysfunctional organisational stove-pipes of the Intelligence Community (IC) will need to be replaced with new organizational cultures and policies that ardently encourages collaboration and information sharing. Sullivan (2005) proposes an IC future that involves "a collaborative and integrated endeavour by a number of analysts within or across agencies" (pp.29).

Thanks, in large part, to information technology advances in the field of CSCW, today, it is increasingly possible to conduct non-collocated collaborative intelligence analysis tasks in real time. Using video in a non-collocated collaborative intelligence analysis situation may be one way of

replicating the non-verbal communicative cues and awareness nuances akin to F2F communications. But with video-mediated communication, people are only able to see one another but maybe not any task-related artefacts (Fussell, Kraut and Siegel, 2000).

However, communication mediated via the shared visual workspace offers a different alternative to distributed collaborating teams: firstly, it gives them the benefit of being able to see similar views of task artefacts at roughly the same time (ibid). Additionally, we will say that the shared visual workspace offers the benefit of a common reference space, where remote teams can interactively explore task-related artefacts in depth. It should also offer them a shared platform to negotiate and construct meanings.

Technologies like eWhiteboards and eTabletops, are some examples of the shared visual workspace. This paper describes a shared visual workspace as:

[“an electronic bounded space with support for instant feedback (or reciprocity), where distributed collaborating teams can share, visualize and interact with task-related artefacts in real time”.]

Common ground, which Clark (1996) refers to as: “the sum of two people’s mutual knowledge, beliefs and suppositions” and so on, is needed to support collaborative intelligence analysis task functions such as a team of analysts: pouring over various artefacts for clues, or filtering out irrelevant data together, or piecing together unrelated events, or hypothesizing about current trends and threat potentials and so on. Likewise, the negotiation of common ground is critical to advancing the cognitive and communicative processes needed to support those actions. In point of fact, a shared understanding of the intelligence task, its context and the motivation behind it, all of which are significant for interpreting and framing of the intelligence request is common ground (Roth et al., 2010).

Firstly, this paper clarifies how different combinations of a *video* (— one basically showing a remote participant’s head and shoulder, hands and work-area, etc.) and *shared visual workspace* communication media influence conversational grounding. Secondly, this paper offers an understanding of how remote teams negotiate and establish common ground around intelligence analysis tasks. This is significant not least because it marks a departure from previous common ground studies around *conversational tasks* that involve the handling of physical objects.

2. RELATED WORK

2.1. The common ground paradigm | shared visual workspace and video-mediated communication

A common ground premise, a certain level of agreement and shared understanding (or mutual knowledge, mutual beliefs, etc.) is required to make almost any form of collaboration work. Common ground is essential for advancing our interaction with others. Monk (2008) describes it as the things we know about the information the other person involved in the same joint activity with us, shares with us. An alternative definition, can be that the construct describes information or knowledge accumulated in the course of our joint activities with others — information which all parties believe they share and know they share (ibid).

In a nutshell, for such a knowledge to be considered *shared*, or *mutual* or *joint*, it has to be held by all involved in that communicative situation; each person has to know that this knowledge is held by the others. To achieve common ground (or arrive at a shared understanding) of what a speaker had intended by his contribution (Monk, 2008), the

people involved interactively construct or negotiate meanings by proactively seeking and providing evidence to one another about what they understand or do not understand (Brennan, 2005; Fussell, Kraut and Siegel, 2000). This process is what is referred to as “*grounding*”. This implies that the state of common ground should change resultantly as the joint activity progresses (Clark, 1996), such that, as people become aware of what one another knows or does not know, through updating the initial common ground they first established at the start of their joint activity, this should help them formulate their responses more appropriately. This should also help them coordinate their joint actions — what they do, when they do it (Brennan, 2005).

Sustaining a high level of common ground in the way we have been describing, is in fact both necessary for and can result in efficient communication. This indicates that an increase in participant’s shared understanding permits more efficient communication. It could also lead to fewer conversational turns (ibid), or turns progressing more rapidly (Convertino et al., 2009), or a drop in the frequency with which they clarify or introduce their presentations.

Responding to a signal received for incomprehension, or if a person pre-empts a possible breakdown, the speaker of the trouble statement may repair the original contribution by repeating it, or rephrasing the statement, or revising his original intention altogether in order to align it with the feedback received from the message recipient (Brennan, 2005). Likewise, to indicate to the other party that they understand, commonly, a person might use words such as “yeah”, “uh-huh”, “m-hm”, “okay”, or “alright”, etc, or non-verbal cues such as head-nods, similar in function to verbal acknowledgements. They may also use a system’s integrated deictic pointing functionalities to signal this.

Ultimately, these grounding actions will require some effort — or costs, to accomplish. Cost in this case refers to the efforts incurred on the part of participants in a communicative situation (Clark, 1996). It is these costs that we refer to in this paper as *conversational grounding effort*. It is founded on the same theoretical frameworks as the principle of *least collaborative effort*, which describes a situation where people engaged in a dialogue invest no more effort in grounding than what is sufficient to advance the discourse (ibid). These may include such costs as: start-up, speech formulation, reception (or reading, or listening), understanding, turn-taking, display, delay and speech-repair.

Typically, interlocutors adapt techniques they use for grounding to the constraints of the current

medium in order to counteract its cost implications (Brennan, 2005). This indicates that the need to compensate for the cost implications for the lack of, or abundance of certain media constraints, drives how people ground their discourse in technology-mediated communication. Further, it has been argued that the specialised features of different media impose different constraints and costs on the exchange of evidence (Axelsson, Abelin and Schroeder, 2003), such that the more constraints a medium can provide, the better that medium is for facilitating common ground and efficient communication (ibid). What this implies is that it may cost more in one medium than in the other to use certain grounding techniques. All in all, media constraints (or affordances) have an effect on grounding costs — they have the potential to significantly alter the costs associated with deploying grounding techniques.

Fussell, Kraut and Siegel (2000), have argued that seeing a partner's visible feedback, or task-related actions, or artefacts on the shared space, can affect a group member's ability to maintain awareness of what the other person is doing and the task artefacts being manipulated; this can also help them plan and formulate their utterances better. But in video-mediated contexts these affordances aren't there — certainly not in the same manner as a shared visual workspace might offer. As such, the associated costs with monitoring group members' awareness may be significantly low in video-mediated collaborative situations (Brennan, 2005), compared to communications mediated via shared visual workspace.

Last of all, the following assumptions apply to this study:

1. "Grounding is efficiency-driven" (Cherubini, Van-Der-Pol and Dillenbourg, 2005), where also the notion of "effort plays a central role" (ibid, pp.2).
2. More than likely, parties engaged in a dialogue will use the best medium available to them that leads to the least collaborative effort (Modi, Abbott and Counsell, 2013).
3. Compared to shared visual workspace media, communications mediated via video may lead to a greater attenuation of the communication cues, or the awareness nuances around task artefacts and people's actions, that support the natural communicative and cognitive processes for grounding.
4. Assuming all three conjectures (1–3) are true, we predict that when teams have access to the duo of video and shared visual workspace media, they are likely to gravitate more towards

the shared visual workspace media, utilising the system's visual cues during grounding to reduce their *conversational grounding effort*.

2.2. Collaborative Intelligence Analysis | Intelligence Informatics | Conversational Tasks

Unlike prior use/impact studies of collaboration technology which have typically focused on simpler conversational tasks, or ones that involve some sort of physical manipulation, the study considered here focuses on tasks that include the complex sensemaking and inference involved in intelligence work. Even so, although intelligence analysis typically involves some sensemaking activities as key tasks, the two constructs are not the same. Naturally, to some, intelligence analysis might mean the same thing as the sensemaking notion of:

["finding meaning from information that often involves activities such as information foraging and hypothesis generation" (Xu et al., 2015)].

Although these factors may also apply to intelligence analysis, we believe, as do Kang and Stasko (2011), that intelligence analysis is a much more complex process than the information foraging and processing course that existing sensemaking models tended to explicate — such as how information flows, how information is transformed and the cognitive and meta-cognitive processes of making sense of information. Equally, intelligence analysis process is anything but sequential as existing sensemaking models depicts (Richards, 2010) — a view which allows us, as do many others, to question the traditional perceptions and utility of these models as representation of intelligence analysis practices. Also, when most people refer to the sensemaking notion, or envision existing sensemaking models, the undertheorized aspects of how analysts work and the social construction of meaning are rarely in play.

What really sets intelligence analysis apart from more general forms of sensemaking and other analytic activities are its volatility and unpredictability (Taylor, 2005). Intelligence failures or delays could also have severe implications for global/national security. It may even result in loss of human life.

In a similar fashion, compared to physical tasks, or other mundane conversational tasks, intelligence analysis tasks involve a greater level of criticality, urgency, task complexity and cognitive workload — also, the sophistication, the different kinds of complementary expertise involved suggests that intelligence analysis tasks require a rich ecology of collaboration support. Additionally, commonly yoked with intelligence analysis are challenges of sharing information across languages, and with fast

tracking a productive and coherent time-sensitive inter-agency collaboration.

An analyst's job is to make sense of a complicated mass of information. He sifts through a diverse range of intelligence information. He assesses them for relevance and the reliability of the sources. Then he strives to identify any anomalies and outliers in the intelligence evidence (Johnston, 2005). Additionally, analysts integrate and process disparate streams of data and link unrelated events in order construct an accurate interpretation of a situation and arrive at analytical decisions (Tecuci et al., 2010), within a constrained time-frame. Equally, intelligence evidence are commonly incomplete. They are often ill structured.

Also, the credibility and reliability of intelligence evidence are sometimes questionable (Tecuci et al., 2010). On top of all that, analysts have to make their forecasts based on evidence that is inconclusive and dissonant to some degree (ibid); they may contain potentially deceptive elements (Taylor, 2005). It is also not uncommon to find intelligence evidence rife with numerous ambiguities and uncertainties (Heuer, 2005); plus they may contain noise data. Intelligence evidence are also mostly heterogeneous in nature (ibid). Further, typically, a team of analysts are asked to collaborate on complex intelligence requests and information requiring high cognitive load, which can have negative effects on task completion, or affect how well they explore, judge or interpret information from the evidence pool, or how well they weigh all alternative viewpoints, or the quality of hypothesis they generate.

In closing, firstly, the review presented in this section establishes some clarity between the notions of sensemaking and intelligence analysis on the one hand, then between simpler conversational tasks and intelligence analysis tasks on the other hand. Secondly, here we sought to establish important dimensions of collaborative intelligence analysis tasks in order to: (1) make clear what parameters would need to be included to make experimental intelligence tasks more realistic (2) develop an understanding of this task, which we hope will offer a useful platform for studying how and to what extent technology would support the usual communicative processes, or cognitive processes, or information sharing processes that underlie the negotiation of meaning with such tasks.

3. METHODS

3.1. Design

To begin, in this experiment, there are two independent variables with two levels; these are:

- shared visual workspace;
- video

The dependent variable (or measure) is: conversational grounding effort.

	Video			No Video	
SVW	audio	video	svw	audio	svw
No SVW	audio video			audio	

Table 1: Study Design

The study design is summarised in Table 1, while Figure 1 shows the different physical setup. To recap, with audio remaining constant, this experimental study compares four independent communication media conditions. Using a factorial 2x2 *between-subjects* design, we explore whether there are differences between these unrelated (independent) groups. The following hypothesis were developed:

- H1.** Teams using shared visual workspace will construct repair-episodes at a lower rate than those without.
- H2.** Teams using video will construct repair-episodes at a lower rate than those without.
- H3.** An association exists between shared visual workspace and video in terms of the rate of repair-episodes.
- H4.** The rate of repair-episodes will decrease as the task progresses.

3.2. Tasks

The study presented used our own modified version of a "Special Operations Reconnaissance (SOR)" Intelligence Analysis Scenario, first developed by Warner et al.,(2008) for the US Navy. The tasks which we describe below, requires analysis teams to apply inductive reasoning skills to a diverse range of intelligence artefacts to discern patterns, identify and link unrelated events, in order to collaboratively arrive at a conclusion.

The SOR scenario is deemed to be both realistic and representative of real-world collaborative intelligence analysis tasks as validated by domain experts. The tasks had enough domain specific attributes and complexities needed to ensure they remained cognitively challenging. To summarise, in framing the SOR scenario, all of the artefacts provided are presumed to bear some connection to an Afghanistan warlord — Demkapsah Farah, who also happens to be working for the US led coalition. Participant pairs were asked to:

- **Task 1:** Assess if Farah has allegiance with a new terrorist cell network recently formed in his home town of Dissibad.

- **Task 2:** Identify the five most plausible events or evidence from the intelligence data which supports any conclusion reached above.

For further references to the full description of tasks see: (Laurence, 2015) — (<http://eprints.mdx.ac.uk/>).

3.3. Setting

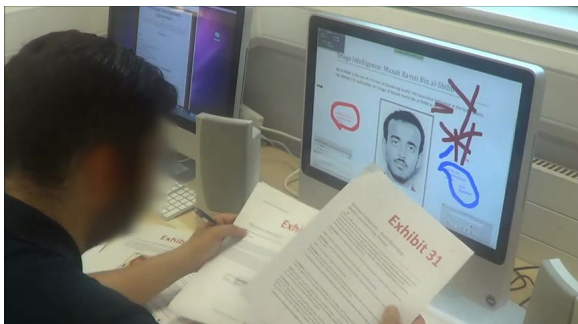
Designed to simulate non-collocated collaborative work, for each experimental trial, a team of two analysts situated at different laboratories completed the collaborative intelligence analysis tasks. Also, we gave each team member two sets of Apple iMacs (with 24-inch widescreen LCDs) — one to use for the collaborative work and the other for completing a post-experiment online questionnaire. This iMac was preconfigured with the system's in-built web-camera and microphone to facilitate videoconferencing; we also provided each member with a pair of speakers positioned on either side of the iMac system. A Cisco WebEx video-conferencing system with embedded audio-conferencing and eWhiteboard functionalities was used for this study — see Figure 2 for illustration.



(a) Shared Visual Workspace | Video



(b) No Shared Visual Workspace | Video



(c) Shared Visual Workspace | No Video



(d) No Shared Visual Workspace | No Video

Figure 1: Participants completing the tasks in the different media set-up

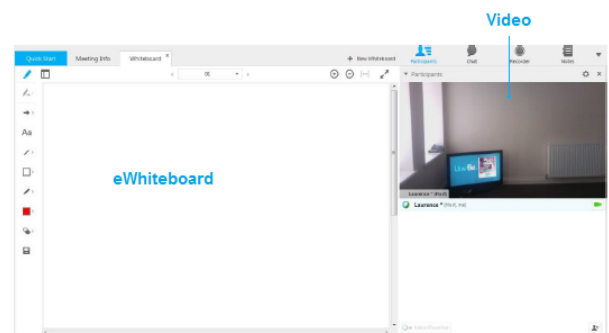


Figure 2: A videoconferencing system with embedded eWhiteboard

3.4. Participants

Approval was obtained from the University's Research Ethics Committee, following that we recruited fifty-six participants made up of twenty-five undergraduate and thirty-one graduate students. Nearly 70 percent of the participant pool were Male, 30.4 percent were Female; their ages ranging from 18-48. Twenty-eight teams of 2-members each were distributed across the four media conditions.

A convenience sampling technique was used. Using this non-probability sampling technique, allowed us to ask people who were easily accessible to us at the time and place when the sampling was conducted, to take part in the human-participant experiment, while also factoring in certain pre-selection criteria such as: participant's ability to communicate fluently in written and spoken English, computer skills and

computer literacy, and prior experience with remote collaboration.

3.5. Procedures

Each trial run began with a pre-task session that lasted 15 minutes, during which participant pairs completed consent forms (the form described the research and asks their permission to be video-taped as they completed the tasks), they were told what their participation would involve and received the task instruction. Further, they received a short technical training specific to the communication mode a group will use in the experiment. After this, they are taken to separate laboratory rooms and where given 30 minutes to consider their task artefacts individually. To stop participants interacting during the individual work, all communication between the two rooms were temporarily disabled.

The pair had one task artefact in common which provided them with historical background information relating to the intelligence scenario. A group member's task portfolio also included 8 or 9 additional intelligence artefacts which were also completely different from the ones the other group member had. Teams using a shared visual workspace media also received soft-copies of these intelligence artefacts to allow for artefact sharing, manipulation and interaction within the shared visual workspace environment. Once the individual work phase was completed, the pair then had 1 hour to collaborate on the intelligence tasks. After that, participants were asked to do a short questionnaire online. This was quickly followed by a debriefing with the experimenter. The post-task activities lasted 15 minutes. Each trial lasted 2 hours. All of the sessions were audio and video recorded.

3.6. Measures

This study compares four independent media conditions in terms of “*conversational grounding effort*”. And in this experiment, we have operated this as the “*number of repair-episodes per min*” (or “*rate of repair-episodes*”). Additionally, guided by this study's theoretical frameworks, this study regards a reduced effort of conversational grounding as proxy for increase in common ground.

4. DATA COLLECTION, RESULTS AND ANALYSIS

Video data from all 28 trials were transcribed and coded using codes from our codebook — this has been created as a synthesis of prior CSCW pre-established coding schemes, and from our assessments of a pilot study we conducted as part of

a much larger study, part of which is reported here. A full description of the codebook and the creative process involved with specifying the common ground coding schema can be found here — (Laurence, 2015). For the analysis next presented here, we used “speech repair” specific codes and code descriptions indicating a dialogue grounding act. These included:

[understanding checks, confirmation checks, repair-requests, sentence completions, alterations, resubmissions, restarts, cancellations, clarifications, paraphrases and repetitions].

At the analysis level, these codes were later combined to form a super-code named: *repair-episodes*. To both ensure and test the reliability of the coding, and our coding scheme, two raters were recruited and trained on code identification, and were instructed on the purpose of the study. Both raters independently coded 26.7% of 5727 words-transcript from one “shared visual workspace|video” trial-run, and 33.6% of 4611 words-transcript from one “no shared visual workspace|video” trial-run. Using Cohen's Kappa reliability statistic:

$$\kappa = \frac{Pr(a) - Pr(e)}{1 - Pr(e)}$$

determined the coding of the first transcript yielded a 75% level of agreement between the raters. With the second transcript, following further discussions with the researcher, an agreement rate of 85% between the raters was achieved.

To test H1, H2 and H3, we report the results of a 2-way-ANOVA which allows us to explore the main effects of shared visual workspace and video on “*conversational grounding effort*” and any existing relationship between them. Hypothesis 4 is answered by a Pearson's correlation test. Table 2 shows the results of the 2-way-ANOVA analysis. All pre-test assumptions were satisfied. There were no outliers in the data. The data was normally distributed for each media condition as assessed by a Shapiro-Wilk test, ($\rho > .05$; the p-values of .089, .420, .869 and .635). Homogeneity of variances criteria was met as assessed by a Levene's Test of Homogeneity of Variance, ($\rho = .056$).

4.1. Shared Visual Workspace Main Effect

Hypothesis 1 predicts that teams using shared visual workspace will construct repair-episodes at a lower rate than those without. ANOVA results of the main effect of “shared visual workspace” were statistically significant. As observed in Table 2, there were more statistically significant differences between the means ($\rho < .05$), for the *rate of repair-episodes*,

Repair Episodes

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power ^a
Corrected Model	.861 ^a	3	.287	1.905	.156	.192	.430
Intercept	102.596	1	102.596	681.113	.000	.966	1.000
SVW Factor	.751	1	.751	4.988	.035	.172	.573
Video Factor	.095	1	.095	.628	.436	.025	.119
SVW Factor * Video Factor	.015	1	.015	.100	.755	.004	.061
Error	3.615	24	.151				
Total	107.072	28					
Corrected Total	4.476	27					

^a. R Squared = .192 (Adjusted R Squared = .091)

^b. Computed using alpha = .05

Table 2: 2-way-ANOVA Tests of Between-Subjects Effects

Repair Episodes

SVW Factor	Video Factor	N	Mean	Std. D	Std. Error	95% Confidence Interval	
						Lower Bound	Upper Bound
no svw	no video	7	1.997	0.538	.147	1.694	2.299
	video	7	2.159	0.283	.147	1.857	2.462
svw	no video	7	1.715	0.455	.147	1.413	2.018
	video	7	1.785	0.160	.147	1.483	2.088

Table 3: Estimated Marginal Means for "Repair Episodes"

($F(1,24) = 4.988$, $\rho = .035$, partial $\eta^2 = .172$) in situations where teams were using the shared visual workspaces than not. This implies that Hypothesis 1 is supported.

4.2. Video Main Effect

Similarly, hypothesis 2 predicts that teams using video will construct repair-episodes at a lower rate than those without. For the main effect of video, the 2-way-ANOVA results presented in Table 2 indicates that there were no significant differences between the means in terms of the *rate of repair-episodes*, ($F(1,24) = .628$, $\rho = .436$, partial $\eta^2 = .025$). Thus, we conclude that Hypothesis 2 is not supported.

4.3. The interaction effect

The descriptive statistics results in Table 3 is presented as mean \pm standard deviation. Among participants using a shared visual workspace, those not using video constructed repair-episodes at a lower rate. The decrease was from $1.79 \pm .16$ (in the *shared visual workspace | video*) group, to $1.72 \pm .46$ (in the *shared visual workspace | no video*) group. Overall, participants using a shared visual workspace, constructed repair-episodes at a lower rate than those not using a shared visual workspace at all: $2.01 \pm .54$ in the *no shared visual workspace | no video* group and $2.16 \pm .28$ in the *no shared visual workspace | video* group.

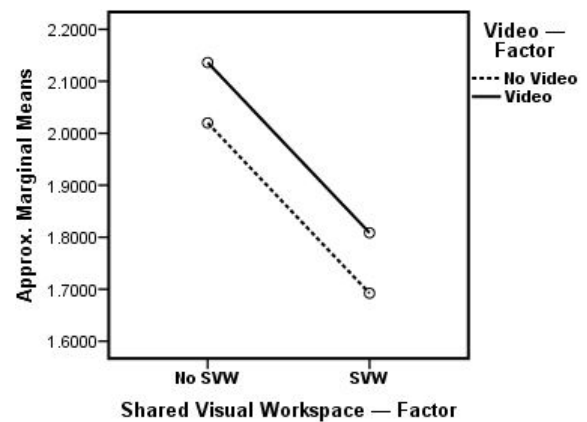


Figure 3: Estimated means for "Repair Episodes"

Looking at Figure 3, we expect to see a significant interaction term, since the lines there are not parallel, however this is not the case. The results presented in Table 2 shows that there are in fact, no significant interaction between shared visual workspace and video media in terms of the *rate of repair-episodes*, ($F(1,24) = .100$, $\rho = .755$, partial $\eta^2 = .004$). Thus, we conclude Hypothesis 3 is not supported. Nevertheless, the ANOVA results, considered in the context of Figure 3, allow us to conclude that, where any signs of interaction exists at all, those effects are being hidden by the main effects in the ANOVA.

4.4. Repairs Over Time As Task Progresses

Hypothesis 4 predicts that the *rate of repair-episodes* will decrease as the task progresses. To test this hypothesis, we conducted a Pearson's correlation test. The test measured the '*rate of repair-episodes*' against the "time period" in the experiment. To analyse this, we elected to test five equal and continuous time intervals: Time points 1-5, across the different media conditions.

Figure 4 and Table 4 show a gradual decline in the *rate of repair-episodes* that teams produced over periods: $T_2 - T_5$. But at T_1 , the *rate of repair-episodes* was higher. Teams made more utterances here. That period correspond with the early stages of the collaboration during which participants exchanged more social pleasantries, or made several attempts to try and establish relevant conventions and strategies for approaching the collaborative intelligence tasks. T_1 was excluded from the Pearson's correlation test we ran.

Repair Episodes

	T_1	T_2	T_3	T_4	T_5
Time	5	10	15	20	25
Mean	15.90	19.37	18.20	16.36	14.44

T_X = Time Point; where X = 1,2, ..5

Table 4: Correlation data

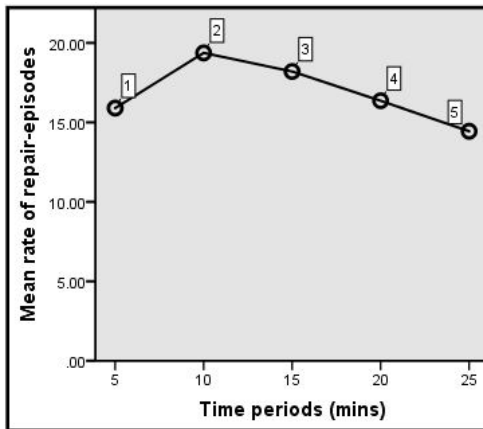


Figure 4: Rate of repair-episodes over time

Focusing on the other time points, results of the pre-tests performed showed there were no outliers in the data as assessed by a visual inspection of a Boxplot. Also, a Shapiro-Wilk's test for normality, demonstrated that the *rates of repair-episodes* over time (i.e., for $T_2 - T_5$), were approximately normally distributed, ($\rho = .972 | .877$). Pearson's correlation results for the relationship between the *rate of repair-episodes* and *time period* were statistically significant ($\rho < .01$; $\rho = -.994$; 2-tailed). These results indicate that there was a strong negative correlation

between the *rate of repair-episodes* and the *time* spent working on the collaborative intelligence task. Thus, Hypothesis 4 is supported.

5. DISCUSSION AND CONCLUSIONS

To begin, the following theoretical frameworks further apply:

- Remote teams utilising a collaborative framework with fewer visual cues might be expected to work harder to maintain common ground. As such we expected to see these teams investing more "*conversational grounding effort*" than others. Likewise, with more visual cues, we predicted that the realistic effort parties commit towards grounding reduces.
- "*Conversational grounding effort*" is a proxy for common ground — such that when the effort of conversational grounding is reduced, this will lead to an increase in common ground (or shared understanding, mutual beliefs, mutual knowledge etc).
- In the experiment presented, we have measured "*conversational grounding effort*" as the "*number of repair-episodes per minute*" (or "*rate of repair-episodes*").

This study have demonstrated that when neither video or shared visual workspace is available to teams, the effort of conversational grounding is increased, meaning that in those situations the teams involved constructed *repair-episodes* at a higher rate. Further, as predicted, teams with access to shared visual workspace constructed *repair-episodes* at a lower rate than those without. Equally, compared to communications mediated via video, the effort of conversational grounding reduces when shared visual workspace is present. Everything considered, these results allows us to conclude that where communication media might have contributed to the grounding process, or how remote teams repaired communication breakdown in particular, those effects differ across four experimental media conditions. We attribute this to the differences in the types of affordances media provides and the attenuation differences of communication cues.

In the collaborative intelligence analysis task, access to the shared visual workspace ensured that teams had a source of visual information throughout the task duration and a shared task space from which they were able to continually infer what a person understands or does not understand. This may explain why the "*rate of repair-episodes*" was demonstrably low for teams using the shared visual workspace compared to those without.

Complementing these results, a post-experiment questionnaire in which we asked participants to rate the “*improvement in mutual agreements and shared understanding as the task progressed*”, determined that there were significant differences between the means in terms of the “*rate of repair-episodes*” where teams had access to the shared visual workspace than those without.

Results of the ANOVA test presented determined that: (a) there were no main effects for video, (b) there were no interaction between video and shared visual workspace. The former outcome align with previous studies where it had been determined that a video of other people’s faces did little to advance team performance in remote tasks.

As Table 3 shows, the *rate of repair-episodes* was lowest when the current communication mode included the shared visual workspace functionality, as opposed to when it didn’t. This allows us to further conclude that having functionalities or support for a shared orientation to task artefacts, yields better dividends in terms of the effort of conversational grounding, while conducting complex collaborative intelligence analysis tasks.

Laurence (2015) have demonstrated several useful ways how non-collocated teams conducting collaborative intelligence analysis tasks deployed the shared visual workspace to facilitate grounding. For example, he found that teams tended to use shared eWhiteboards for articulating difficult or indescribable words. Categorizing the results of an in-depth qualitative analysis of experimental video data against the themes below, he further determined that teams with access to shared eWhiteboards tended to use this as a resource for:

1. Minimizing communicative effort.
2. Repairing communication breakdown.
3. Monitoring comprehension.
4. Authenticating, or clarifying the correctness of active or prior presentation.
5. Facilitating conversation, or introducing, or completing presentations.
6. Maintaining awareness.
7. Performing several joint activities including: mind-mapping and drawing inferences.
8. Deictic pointing referencing and making representations.

The correlation results presented determined that *rate of repair-episodes* reduces as collaborative task progresses. This is true for all communication modes. While this particular result is further prove that the “*conversational grounding effort*” measure is appropriate for measuring the common ground construct, the correlation results presented,

qualifies Clark (1996)’s account that common ground generally increases as task progresses.

5.1. Limitation

As we expected, a fusion of the trio research disciplines: common ground, intelligence analysis and collaborative systems, ensured that this study was very challenging. Additionally, the rudimentary hiccups and issues with conducting a study in the intelligence domain were in play (— e.g. the difficulty in recruiting intelligence personnel, or securing the cooperation of intelligence institutions, or concerns about the intelligence discipline being typecast in secrecy etc.). Some people may see them as limitations of the study. But, these limitations are common to many studies in this domain.

To minimize the effects of participant’s existing affiliations between team members (which some may see as a limitation of the study), we deliberately included a diverse range of task documents for which participants were unlikely to have a shared language (or common ground).

Some may take the view that the use of students may make it harder for us to generalise our results outside the scope of our work, to that we say that prior arguments have stated that the same “cognitive processes and limitations apply across all population” (Hayne, Troup and McComb, 2011)(pp.98) — we believe this to be case.

5.2. Future research direction

Although the results presented have effectively compared the *rates of repair- episodes* between different combinations of video and shared visual workspace, it could be further developed in a number of ways. Perhaps by making a start on demonstrating the performance differences of the intelligence scenario-based tasks, on shared visual workspace and video, this could provide a deeper understanding on the role specific features of the intelligence task plays in the grounding process. Going forward, to give further weight to the findings presented and perhaps shed a deeper understanding to them, it may be necessary to assess whether participants learn strategies for improving common ground through a shared knowledge of relevant “experience” with using video and shared visual workspace.

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